

CLAIMS

What is claimed is:

- 1 1. An apparatus comprising:
  - 2 a) a bulk element having a device surface and a bottom surface, disposed below
  - 3 said device surface;
  - 4 b) a support; and
  - 5 c) at least one hinge, which is disposed below said bottom surface, and which is
  - 6 coupled to said bulk element and to said support, thereby suspending said bulk
  - 7 element from said support.
- 1 2. The apparatus of claim 1 wherein said bulk element comprises single-crystal silicon.
- 1 3. The apparatus of claim 1 wherein said device surface is reflective.
- 1 4. The apparatus of claim 3 wherein said device surface comprises a reflective layer.
- 1 5. The apparatus of claim 4 wherein said reflective layer comprises a material selected  
2 from the group consisting of gold, aluminum, silver, and copper.
- 1 6. The apparatus of claim 1 wherein said at least one hinge is formed from a material  
2 selected from the group consisting of polysilicon, polyoxide, nitride, silicon nitride,  
3 silicon dioxide, silicon oxynitride, single-crystal silicon, and metals.
- 1 7. The apparatus of claim 1 wherein said support is made of silicon.
- 1 8. The apparatus of claim 1 wherein said support includes a cavity, and wherein said at  
2 least one hinge is disposed within said cavity.

- 1 9. The apparatus of claim 8 wherein said support further comprises at least one electrode  
2 disposed in said cavity, for causing said bulk element to be actuated.
- 1 10. The apparatus of claim 8 wherein said cavity is formed by a plurality of sidewalls.
- 1 11. The apparatus of claim 10 wherein said at least one hinge comprises first and second  
2 hinge elements, and wherein each of said hinge elements is coupled to a unique one  
3 of said plurality of sidewalls.
- 1 12. The apparatus of claim 11 wherein each of said sidewalls includes a ridge portion that  
2 is inwardly projecting, and wherein each of said hinge elements is coupled to a  
3 unique one of said ridge portions.
- 1 13. The apparatus of claim 12 wherein each of said hinge elements is further coupled to  
2 said bottom surface.
- 1 14. The apparatus of claim 11 wherein said bulk element further comprises a base portion  
2 which extends downward from said bottom surface, and wherein each of said hinge  
3 elements is coupled to said base portion.
- 1 15. A method of making a MEMS apparatus, comprising:  
2 a) providing a device component comprising single-crystal silicon;  
3 b) creating at least one hinge in said device component;  
4 c) constructing a support component having a cavity;  
5 d) bonding said device component to said support component, such that said at  
6 least one hinge is disposed within said cavity; and  
7 e) forming in said device component a bulk element having a device surface and  
8 a bottom surface, whereby said at least one hinge is coupled to said bulk  
9 element and is disposed below said bottom surface, thereby suspending said  
10 bulk element from said support.

- 1 16. The method of claim 15 wherein said device component comprises an SOI (Silicon-  
2 On-Insulator) wafer having a single-crystal silicon device layer and a silicon handle  
3 wafer sandwiching an insulation layer, said single-crystal silicon layer having a first  
4 surface.
- 1 17. The method of claim 16 wherein said at least one hinge comprises first and second  
2 hinge elements, fabricated on said first surface of said single-crystal silicon device  
3 layer by a surface micromachining technique.
- 1 18. The method of claim 16 wherein said at least one hinge is created in said single-  
2 crystal silicon device layer by a bulk micromachining technique.
- 1 19. The method of claim 17 wherein said step d) further includes removing said silicon  
2 handle wafer along with said insulation layer, thereby revealing a second surface of  
3 said single-crystal silicon device layer.
- 1 20. The method of claim 19 wherein said step e) includes using a bulk micromachining  
2 technique to form said bulk element in said single-crystal silicon device layer,  
3 whereby said first and second surfaces of said single-crystal silicon device layer  
4 constitute said bottom and device surfaces of said bulk element.
- 1 21. The method of claim 15 further comprising the step of making said device surface  
2 optically reflective.
- 1 22. The method of claim 21 wherein said device surface is made optically reflective by  
2 depositing a reflective layer thereon.
- 1 23. The method of claim 15 wherein said device component comprises an epitaxial  
2 silicon wafer.
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- 1 24. The method of claim 15 wherein said support component is fabricated out of an SOI  
2 wafer.  
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- 1 25. The method of claim 15 wherein said step c) further includes disposing at least one  
2 electrode in said cavity.
- 1 26. An optical apparatus comprising:  
2 a plurality of MEMS devices configured in an array, wherein each MEMS device  
3 includes:  
4 a) a bulk element having a device surface and a bottom surface, disposed below  
5 said device surface;  
6 b) a support; and  
7 c) at least one hinge, which is disposed below said bottom surface, and which is  
8 coupled to said bulk element and to said support, thereby suspending said bulk  
9 element from said support.
- 1 27. The apparatus of claim 26 wherein said bulk element comprises single-crystal silicon.
- 1 28. The apparatus of claim 26 wherein said at least one hinge comprises first and second  
2 hinge elements.
- 1 29. The apparatus of claim 26 wherein said at least one hinge is formed from a material  
2 selected from the group consisting of polysilicon, polyoxide, nitride, silicon nitride,  
3 silicon dioxide, silicon oxynitride, single-crystal silicon, and metals.
- 1 30. The apparatus of claim 26 wherein said device surface is optically reflective.
- 1 31. The apparatus of claim 26 wherein said support contains a cavity, and wherein said at  
2 least one hinge is disposed within said cavity.

- 1 32. The apparatus of claim 31 wherein said support further comprises at least one  
2 electrode disposed in said cavity, for causing said bulk element to be actuated.

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